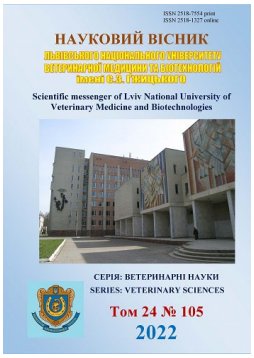

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Influence of technological factors on milk quality indicators

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The article presents a study of the organization of milk production technology on the farm with tethered and tethered-boxing of cows. It has been established that one of the departments uses Dairy Plan C21 herd management software. This makes it possible to obtain comprehensive data on milk productivity, health, and behavior of each cow, group of animals, and the herd. Pre- and post-milking treatment of cows' teats with means based on a probiotic culture of Bacillus subtilis, Forticept® Udder Wash, and Zooprotect. According to the research results, data on production and sales were obtained, and indicators of quality and safety of whole raw milk from two departments were analyzed. Gross milk production for the year at section 1 with free-range boxing of cows was 1875.4 tons, the average annual yield per cow – 7381 kg, milk marketability – 96.3 %. The production figures for section № 2 with tethered animals were – 1324.2 tons, 7333 kg, and 96.5 %, respectively. The study found that the average annual amount of MAFANM in milk from cows at tethered housing was 37 ± 3.6 × 10^4 thousand CFU/cm^3; loose-box – 35 ± 4.1 × 10^4 thousand CFU/m3; the number of somatic cells is 327.8 ± 28.73 and 332.1 ± 29.91 thousand cm^3, respectively. In the milk of cows from section № 2 the protein content was 3.19 ± 0.067 %, fat – 3.78 ± 0.106 %, fat/protein ratio – 1.18 : 1. Slightly higher values were obtained when studying cows' milk from the sections № 1 – 3.22 ± 0.033; 3.88 ± 0.093 %, and 1.21 : 1, respectively. According to normative indicators, the fat/protein ratio is 1.2–1.4 : 1. It should be noted that deviations from these indicators indicate a violation of metabolic processes in cows. Indicators of acidity and density in cow's milk were within the normative values. According to research, no heavy metals, pesticides, radionuclides, or inhibitors have been detected in whole raw milk. Therefore, analyzing the data obtained, it should be noted that the milk produced on the farm and sold to processing enterprises meets the requirements for quality milk. According to the national standard, it is suitable for producing quality and safe products.

Key words: *technology, dairy cows, productivity, udder hygiene, milk quality, bacterial contamination, somatic cells.*

Вплив технологічних чинників на показники якості молока

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У статті наведено дослідження організації технології виробництва молока в господарстві за прив'язного і безприв'язно-боксового утримання корів. Встановлено, що на одному з відділків використовують програмне забезпечення управління стадом Dairy Plan C21. Це дає можливість отримувати комплексні дані щодо молочної продуктивності, стану здоров'я і поведінки, як кожної окремої корови, групи тварин так і стада в цілому. Вивчено, що перед-і після доїльну обробку шкіри дійок корів проводять засобами на основі пробіотичної культури Bacillus subtilis, препаратами Forticept® Udder Wash і Зоопротект. За результатами досліджень отримано дані щодо виробництва і реалізації, проаналізовано показники якості і безпечності сирого збірного молока з

двох відділків. Валове виробництво молока за рік на відділку № 1 з безприв'язно-боксовим утриманням корів становило 1875,4 тонн, середньорічний надій на одну корову – 7381 кг, товарність молока – 96,3 %. Виробничі показники на відділку № 2 з прив'язним утриманням тварин були – 1324,2 тонн, 7333 кг і 96,5 % відповідно. Дослідженням встановлено, що середньорічні показники кількості МАФАнМ у молоці корів за прив'язного утримання становили 37 ± 3,6 × 10^4 тис. КУО/$см^3$; безприв'язно-боксового – 35 ± 4,1 × 10^4 тис.КУО/$см^3$; кількість соматичних клітин 327,8 ± 28,73 і 332,1 ± 29,91 тис/$см^3$ відповідно. У молоці корів відділення № 2 вміст білку становив 3,19 ± 0,067 %, жиру – 3,78 ± 0,106 %, співвідношення жир/білок – 1,18 : 1. Дещо вищі показники були отримані за дослідження молока корів відділення № 1, які становили – 3,22 ± 0,033, 3,88 ± 0,093 % та 1,21 : 1 відповідно. Відповідно, за нормативного показника, відношення жир/білок 1,2–1,4 : 1. Слід відзначити, що відхилення від цих показників свідчить про порушення метаболічних процесів в організмі корів. Показники кислотності та густини молока корів знаходилися в межах нормативних значень. За результатами досліджень у сирому збірному молоці не виявлено важких металів, пестицидів, радіонуклідів та інгібувальних речовин. Отже, аналізуючи отримані дані слід відмітити, що молоко, яке виробляється в господарстві і реалізується на переробні підприємства відповідає вимогам до якісного молока. Згідно національного стандарту воно є придатним для виготовлення якісної і безпечної продукції.

Ключові слова: *технологія, дійні корови, продуктивність, гігієна вимені, якість молока, бактеріальне обсіменіння, соматичні клітини.*

Introduction

The dairy industry is an essential part of agricultural production, both in terms of labor and material resources and the cost of production. Dairy farming is developing in almost all agricultural enterprises of Ukraine. This is facilitated by relatively favorable conditions in the agricultural sector, large areas of onions on farms, and a developed structure of forage crops in crop rotation (Petrichenko, 2017; Radko & Bidula, 2017).

Stable high milk productivity of cows can be achieved due to the corresponding genetic potential and analytical technologies for feeding and keeping cattle (Evink & Endres, 2016; Petrov et al., 2016). The milk production process should be ensured by fulfilling the main tasks on the farm: increasing the productivity of animals and continuing their economic use, reducing the cost of production and its high quality, and ensuring the environmental safety of production.

The primary link where milk quality is formed is a farm or complex that works on specific technologies. Nevertheless, regardless of the production components, the product must have quality characteristics due to the composition properties of nutritional, biological, and energy value. That is why the milk quality management system should focus on technological production processes and its primary processing (Paliy et al., 2020; Lopreiato et al., 2020; Rajola-Schultz et al., 2021).

Reserves to increase the production of high-quality products are determined in the comprehensive analysis of technologies used in the economy. In this regard, there is a need for a comprehensive study of the state and directions of development of milk production, identifying the main ways of rational use of technology and increasing their efficiency.

The work aims to analyze the milk quality and the sales level depending on the technology of its production in the LLC "Agroholding 2012" Khmelnytsky region.

Materials and methods

In the course of the work, the analysis of the existing technologies of milk production, indicators of its quality, and level of realization in the conditions of LLC "Agroholding 2012" during 2021 was carried out. Determination of milk quality indicators was carried out in Khmelnytsky Regional State Laboratory of the State Service for Food Safety and Consumer Protection, Dunayevets Interdistrict State Laboratory of the State Food and Consumer Service, and Test Laboratory of SmartBioLab LLC (Kharkiv).

The material for the study was 320 dairy cows of the black-spotted breed. The stall system with tethered maintenance is used on the dairy farm of department № 2, where there are 136 cows, milking cows twice, in the milk line. H 12 and Z 2 products based on the probiotic culture of Bacillus subtilis are used to treat cows' udders before and after milking. These are clear, oily, odorless liquids. According to the instructions for use, the concentrate was diluted in water at a temperature of 40 °C and kept for 6–8 hours near a heat source. The working solution was applied using a sprayer, which allows disinfection of both the teats' surface and the udder's skin.

All experimental interventions were carried out in compliance with the requirements of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes (Strasbourg, 1985) and the decisions of the First National Congress on Bioethics (Kyiv, 2001).

On the dairy farm of department № 1, year-round stable free-range and boxing of animals are used. The department keeps 184 dairy cows, milking three times, carried out in the milking parlor. Forticept® Udder Wash is used to treat the skin of teats and udders of cows before milking. It is a safe and effective disinfectant containing natural ingredients. It contains benzalkonium chloride (0.13 mg/ml), chamomile extracts, and yarrow. The working solution is prepared by diluting the drug in water (1 : 3). It has detergent, disinfectant, and foaming properties. The tool is applied with glass by immersing the udder teats for 15 seconds. The tool is used by complete immersion of the udder teats in the working solution of the drug for 15 seconds. The first streams of milk are milked, and the udder is thoroughly dried with a disposable napkin. To preserve the udder of cows after milking, teats are treated with Zooprotect (Sanvet, Ukraine). The product is ready to use and contains iodine, organic acids, and anti-inflammatory components. It has bactericidal and fungicidal properties and has anti-inflammatory and regenerating effects. This ensures fast and effective skin disinfection and creates reliable protection for teats.

Based on the reporting documentation, the analysis of quality and realization of milk depending on production

technologies within 12 months was carried out. The amount of sold milk in physical mass and terms of essential milk (kg) and mass fraction of fat (%) was taken into account during the research. The characteristics of milk that form its grade were also determined. The national standard DSTU 3662: 2018 was used as the normative value of milk grade. "Specifications" (DSTU 3662:2018). Samples of whole raw milk were taken to comply with DSTU ISO 707: 2002. Bacteriological studies were performed following DSTU IDF 100B-2003; the total number of mesophilic aerobic and facultative anaerobic organisms (MAFAnM) was determined following DSTU 7557: 2013; the number of somatic cells – DSTU 7672: 2014. Studies of physicochemical parameters of milk included: determination of protein content – DSTU ISO 8968-1: 2005; fat content – DSTU ISO 1211: 2002; densities – DSTU 6082: 2009; acidity – GOST 3642: 92. The inhibitory substances assessed milk's safety – DSTU 8397: 2015; radionuclides – GH-6.6.1.1-130-2006; pesticides – MB 3222-85; heavy metals: arsenic – MU GRG-107-2005; mercury – MV-04-06; lead, cadmium – GOST 3078-96.

Statistical processing of the obtained data was performed using Microsoft Excel 2017. The arithmetic mean (M) and its error (m) were determined.

Results and discussion

According to the developed scheme at the beginning of the study, the analysis of milk production technology on the farm was carried out. It is established that it meets the existing requirements.

Thus, the reconstruction of livestock premises with cows kept on a dairy farm on the № 2 dairy farm improved the conditions for cattle. Due to the relatively small investment, this has become an attractive alternative to free-range boxing.

In Ukraine, according to the Association of Milk Producers, the share of cows on a leash is about half of the total herd. The main requirement for cows to be tethered is their suitability for machine milking (Popko, 2020). Distribution of fodder on the farm is mechanized, carried out twice with the help of a feed distributor brand "Bpvkun". The feeding of cows is carried out according to the established norms, according to rations for each technological group–watering animals – from automatic drinkers. Next to the drinkers are special containers for feed additives. Milking of cows is carried out by the milking unit "Braclav company" (Ukraine). Milk is transported in a container for primary processing and temporary storage. Cows are harvested on playgrounds with canopies, and there is also a fodder table. Free-range boxing of cows on rubber mats, which is used on a dairy farm, department № 1 is considered more progressive (Fig. 1). Cows are fed on mixed rations. Distribution of feed twice, using a feed mixer brand "Ermes". Keeping animals close to natural conditions provides them with well-being; high biological activity increases the body's resistance and improves reproductive capacity (Cronin et al., 2014).

a b

Fig. 1. Free-range keeping of cows: a – premises, b – feeding grounds

Milking of cows is carried out in the milking parlor with a "Yalinka" type unit for 24 places (Fig. 2). The machines are equipped with milking machines and other means to control and control the process of milking and animal care.

In current conditions, for the successful conduct of dairy farming at the professional level, it is necessary to consider the primary factors and control their dynamics. Detailed information is needed to plan activities, monitor milk production and livestock reproduction, and control the feeding and health of cows. The obtained data are analyzed and quickly integrated into the existing herd management system (Dersk et al., 2014). The department uses Dairy Plan C21 herd management software. Identification of cows is carried out during milking with the help of respondents. Information from the digital chip built into the collar is transferred to the file (Fig. 3).

Fig. 2. Milking machine type “Pine tree”

Fig. 3. Cows with a responder

Electronic animal recognition is necessary for automated registration and data processing of all cows. We get a comprehensive picture of each animal's milk productivity, health, and behavior. The availability of reliable indicators for each individual cow, group of animals, and the herd is the basis of the daily activities of the farm.

Our research analyzed the milk productivity of cows on the farm and the sale of products to processing plants. A total of 21.176 tons of milk was produced during the year. The average annual yield per cow on the farm was 7.158 kg of milk. Gross milk production per year on a dairy farm with loose and box maintenance was 1875.4 tons, the average annual yield per cow – was 7381 kg, and marketability was 96.3 % (Table 1). The production figures for tethered maintenance were 1324.2 tons, 7333 kg, and 96.5 %, respectively. The fat content of milk sold on the farm of department № 1 was – 3.88 % and № 2 – 3.78 %, respectively.

Table 1
Production and sale of milk on the farm

Indicators	Department № 1 Loose-fitting boxing	Department № 2 Tethered hold
Average annual milking per cow, kg	7381	7333
Gross milk production per year, t	1875.4	1324.2
Sales of milk by physical weight, t	1630.9	1181.6
Mass fraction of fat in milk, %	3.88	3.78
Marketability of milk, %	96.3	96.5

The increased bacterial contamination of milk results from non-compliance with sanitary and hygienic requirements during production and storage. High bacterial contamination leads to poor taste, the reduced nutritional value of raw milk and products made from it, and significantly reduced shelf life. Processing plants that use modern technologies cannot use such raw materials and produce high-quality and safe products (Dugdill et al., 2013).

Analyzing the indicators of bacterial contamination of milk obtained by different production technology, it should be noted that they differed slightly in departments (table 2).

The indicators of bacterial contamination of milk obtained from cows of different departments differed slightly, which, in our opinion, is due to different technologies of its production.

The average annual indicators of the amount of MAFAnM in raw milk from a dairy farm with tethered and untethered boxing content were $37 \pm 3.6 \times 10^4$ and $35 \pm 4.1 \times 10^4$ thousand CFU/cm^3, respectively. Bacterial insemination of milk is significantly increased mastitis in cows. The quantitative and species composition of bacteria found in cows' milk with mastitis depends on the form of mastitis, its course, and the type of pathogens (Pyz-Łukasik et al., 2015).

Table 2
Number of MAFAnM and somatic cells in whole raw milk

Indicators	Department № 1 Loose-fitting boxing		Department № 2 Tethered hold	
	MAFAnM, thousand. CFU/cm^3	Amount of somatic cells, thousand/cm^3	MAFAnM, thousand CFU/cm^3	Amount of somatic cells, thousand/cm^3
Lim	1.7×10^5–4.9×10^5	205–397	$2{,}0 \times 10^5$–4.9×10^5	254–451
M ± m	$35 \pm 4.1 \times 10^4$	327.8 ± 28.73	$37 \pm 3.6 \times 10^4$	332.1 ± 29.91

An essential indicator of milk quality and its suitability for processing is the number of somatic cells. The latter are dead cells of the mammary ducts and alveoli, which are involved in milk secretion. They are constantly in the milk. This indicator is essential for the manufacturer and is a valuable tool that cares about the quality of raw materials. However, to use it properly, you need to understand what level is considered normal and what indicates its increase (Silanikove et al., 2014).

The milk of cows with mastitis significantly increases the number of somatic cells. They are characteristic of the inflammatory process – leukocytes, epithelial cells of the breast, erythrocytes, bacteria. Milk with high somatic cell content is technologically defective. According to the European Union standard, the content of somatic cells is allowed not more than 250 thousand/cm^3, and according to the Ukrainian – 500 thousand/cm^3 (Paliy et al., 2019).

In the collective milk of cows of department № 1, the number of somatic cells was slightly lower than in department № 2, with the number of somatic cells in the milk of cows of division № 2 amounted to 327.8 ± 28.73 against 332.1 ± 29.91 thousand/cm^3 in accordance. These indicators meet the requirements of the highest grade.

Modern milk processing technologies place high demands on the quality of raw materials, which is primarily determined by their physicochemical and technological properties.

Academician I. P. Pavlov called milk a “wonderful food” prepared by nature itself. He determined that the human body completely absorbs this product. Milk is synthesized in the breast from components that come from the blood. Passing blood through the alveoli, there is an active transformation of absorbed substances into milk components. The chemical composition of milk and its properties depend on many factors (breed, lactation stage, productivity, feeding, season, health, etc. (Shkromada et al., 2019).

The results of studies of physicochemical properties of milk obtained from cows of different departments are shown in table 3.

In general, we note the low level of protein in the milk of cows of compartment № 2 (3.1–3.3; 3.19 ± 0.067%), fat – medium (3.6–3.9; 3.78 ± 0.106 %). Higher protein content was observed in the milk of cows of compartment № 1 (3.1–3.3; 3.22 ± 0.033%), fat - satisfactory (3.6–4.2; 3.88 ± 0.093 %).

Low protein in milk indicates a lack of energy in the diet, and high – is an excessive amount. A high percentage of fat and low protein means that cows do not get enough energy from feed, and the body is actively breaking down fat. This is one of the symptoms of subclinical ketosis (Dersk et al., 2013).

Table 3
Physico-chemical parameters of raw milk

Indicators	Fat content, %	Protein content, %	Density, kg/m^3	Acidity, °T
Department № 1 (Loose-fitting boxing)				
Lim	3.6–4.2	3.1–3.3	1027–1029	17.0–17.5
M ± m	3.88 ± 0.093	3.22 ± 0.033	1028.3 ± 0.39	17.2 ± 0.18
Department № 2 (Tethered hold)				
Lim	3.6–3.9	3.1–3.3	1027–1029	17.2–18.0
M ± m	3.78 ± 0.106	3.19 ± 0.067	1028 ± 0.38	17.5 ± 0.15

The supply of dairy cows with carbohydrates and protein is controlled by determining and analyzing the fat/protein ratio in milk, the typical values of which are 1.2–1.4 : 1. In dairy cows from departments № 2 and № 1, the fat/protein ratio was 1.18 : 1 and 1.21 : 1, respectively.

Reducing this value to 1: 1 indicates the need for a detailed analysis of the main parameters of the diet, and its increase over 1.4 indicates the course of ketosis in cows (Vovkotrub, 2018). The content of fiber, starch, and fat in the diet's dry matter must correspond to their norm. Thus, the content of starch did not exceed 28 %, crude fat – 7 %, and fiber was at least 16 % of the diet's dry matter.

One of the indicators of milk quality is titrated acidity, which characterizes the freshness of the product obtained from healthy animals. The acidity of fresh milk is 16–18 °T. In our studies, this indicator was within the normative values.

The density of milk is determined by the dry matter content and characterizes the product's naturalness. Its value in milk ranges from 1.027 to 1.032 kg/m^3. It should be noted that during the research period, whole milk from both departments was sold with a density of 10.27–10.28 kg/m^3. According to such safety indicators as the content of heavy metals, pesticides, radionuclides – milk should not exceed the maximum allowable values according to the standard's requirements. As a result of research, it was found that the content of heavy metals (lead, cadmium, mercury, arsenic) was within the maximum allowable levels. The content of pesticide residues and radionuclides in the studied milk samples did not exceed the normative values.

Milk is not allowed to contain inhibitory substances (detergents, preservatives, formaldehyde, sodium bicarbonate, hydrogen peroxide). Their entry may be due to non-compliance with the requirements for the concentration of detergents and disinfectants and violation of the washing regime of milking equipment (Kitikov & Romaniuk, 2017).

After milking, hygienic products for udder treatment should not show inhibitory properties, dry quickly, and be removed entirely. The use of antibiotics in dairy farming should be regulated by appropriate instructions and guidelines (Persson et al., 2016). The studies did not establish the presence of inhibitory substances in the milk of cows in both departments. Milk produced on the farm and sold to processing enterprises meets the requirements for quality milk suitable for the production of dairy products.

Conclusion

The use of various milk production technologies in dairy cattle breeding should create comfortable housing conditions, a proper level of feeding, and a high organization of milking cows. Programmed herd management provides control of animal health and milk production and optimizes dairy farms' productivity.

It was found that the physicochemical parameters of milk obtained from cows on loose housing differed slightly, namely: there was a higher protein content (3.1–3.3; 3.22 ± 0.033 %), fat – satisfactory (3.6–4.2; 3.88 ± 0.093 %), against low protein levels (3.1–3.3; 3.19 ± 0.067%), fat – medium (3.6–3.9 3.78 ± 0.106 %) compared with the milk of cows obtained by tethering. The research results indicate the prospects for implementing organizational and technological measures to increase production and improve the quality and safety of raw milk in the economy.

Information about conflicts of interest

The authors state that there is no conflict of interest.

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